Influence of rainfall on the motion of tropical cyclone across Taiwan topography

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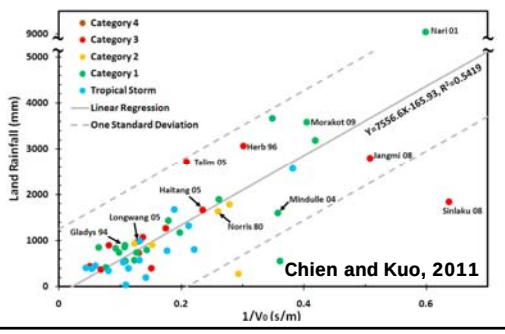
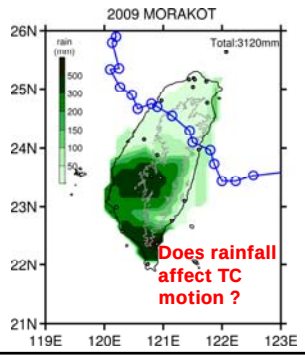
Motivation

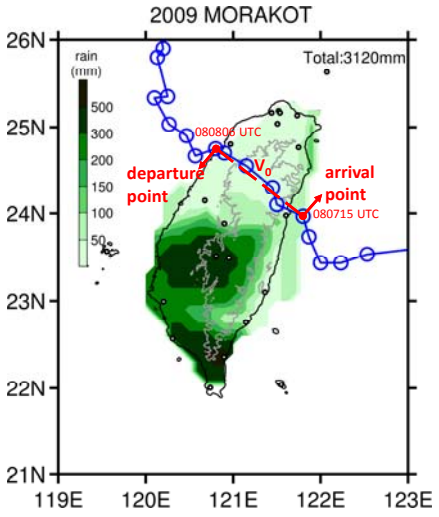
- **Slow moving typhoons with heavy rainfall** often cause serious disaster to Taiwan.
- Land rainfall amount is roughly proportional to the inverse of TCs' translation speed over land. (Chien and Kuo, 2011)



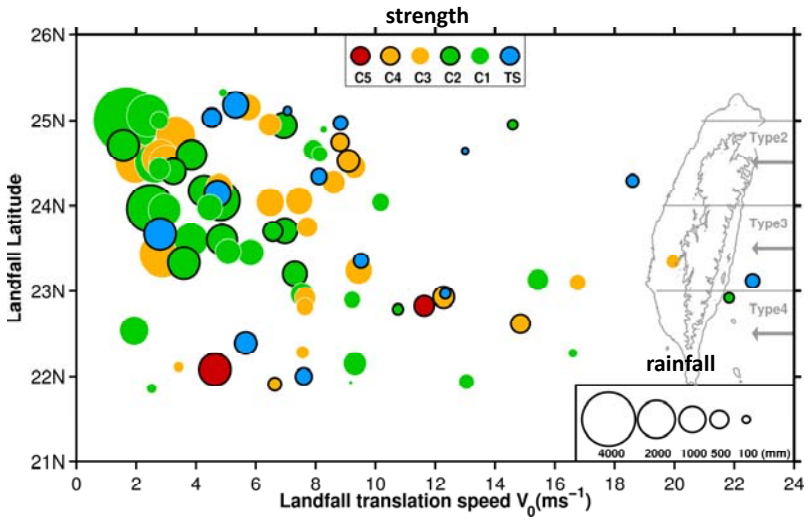


Observation analysis

- **Objects**
  - 1960-2010 westward landfall typhoons (84)
- **Tracks**
  - Typhoon database of CWB, Taiwan
- **Strength before landfall**
  - TC maximum wind speed before landfall in typhoon database of CWB, Taiwan
- **Rainfall**
  - 21 CWB surface stations

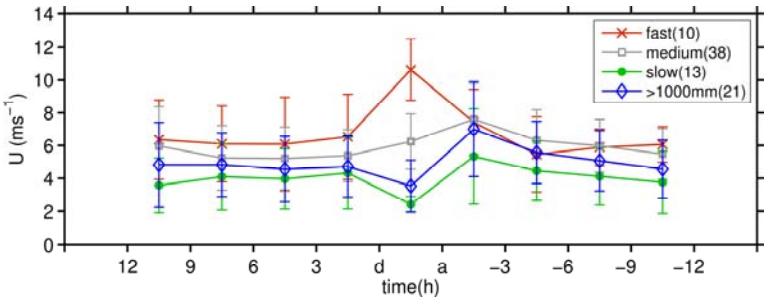


The rainfall amount during landfall over 21 CWB surface stations 1960-2010



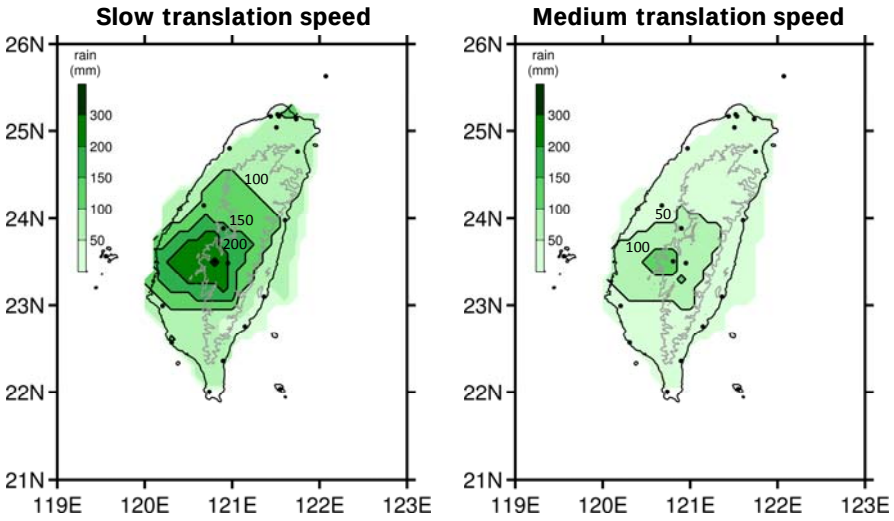
The 3 hourly mean translation speed

Classify TCs as **fast**, **medium** and **slow** groups by the **average ± 1 std.** of translation speed over land



The translation speed of slow moving and large rainfall group decrease after landfall !

Composite rainfall during landfall



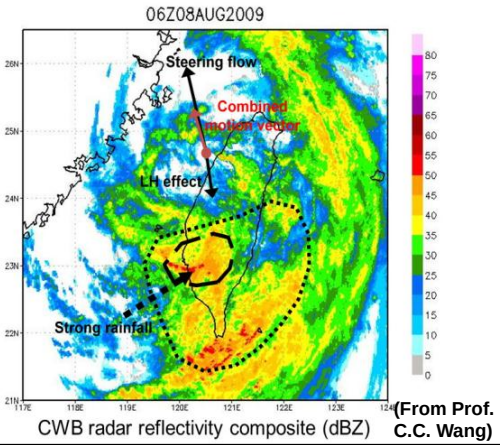
Phase locked by Taiwan terrain (similar to landfall north TC cases in Chang et al., 1993)

Remarks of Observation analysis

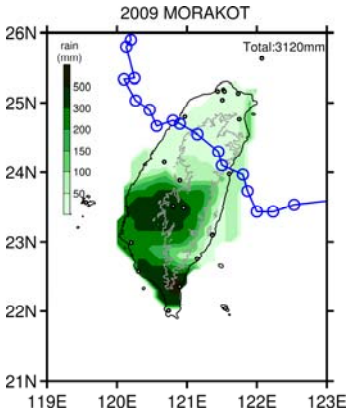
- **Remarks**
  - Large rainfall, slow moving speed, more north landfall position.
  - Decrease of translation speed in slow, large rainfall TCs after landfall.
  - Phase locked rainfall pattern. (TCs at >23° N – southwest rainfall maximum in CMR) (Chang et al., 1993, Lee et al., 2006, Cheung et al., 2008)

Hypothesis

- **Topography phase locked rainfall diabatic heating may have a positive feedback on the slowdown of typhoon motion.**



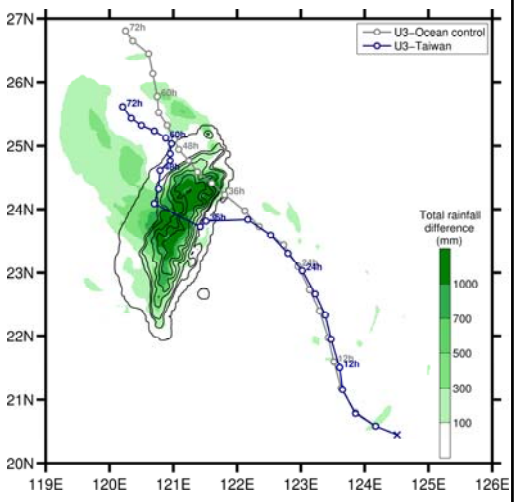
(From Prof. C.C. Wang)



Model setting

Modified WRF Ver. 3.1.1
(Fovell and Su, 2007; Fovell et al., 2009,2010; Cao et al., 2011)

- **Domain** : 1500 km x 1500 km
- **Horizontal resolution** : 5 km
- **Vertical** : 35 sigma levels
- **Votex initialization** :Rankine
  - V_m=50 ms^{-1}, R_m=50 km
- **Terrain** : Taiwan (land free)
- **Uniform mean flow** : -3 ms^{-1}
- **Fixed SST**: 29° C
- **Microphysics scheme**: Lin et al.
- Jordan's (1958) hurricane season sounding



Potential vorticity tendency diagnostic

(Wu and Wong,2000)

- **From moving reference frame**

$$\left(\frac{\partial P}{\partial t}\right)_m = \left(\frac{\partial P}{\partial t}\right)_f + \mathbf{C}\cdot\nabla P$$

- **If we look for wave #1 component**

$$\left(\frac{\partial P}{\partial t}\right)_{1f} = -\mathbf{C}\cdot\nabla P_s$$

PV tendency comes from: $\left(\frac{\partial P}{\partial t}\right)_1 = HA_1 + DH_1^*$ $\quad DH_1^* = (VA_1 + DH_1)$

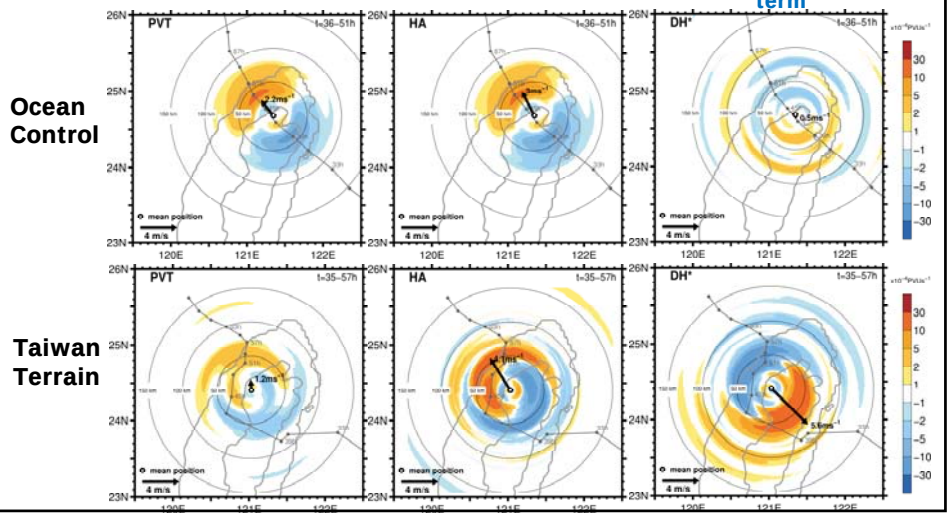
- **Using the least square method by minimizing**

$$\sum_{i\le N}\left[\frac{\sum_{k=7}^{15}\left(c_x\left(\frac{\partial P_s}{\partial x}\right)_i + c_y\left(\frac{\partial P_s}{\partial y}\right)_i + \left(\frac{\partial P}{\partial t}\right)_{1i}\right)_k}{9}\right]^2$$

[Average from level 7-15 (~1-6 km above terrain)]

Potential vorticity tendency diagnostic

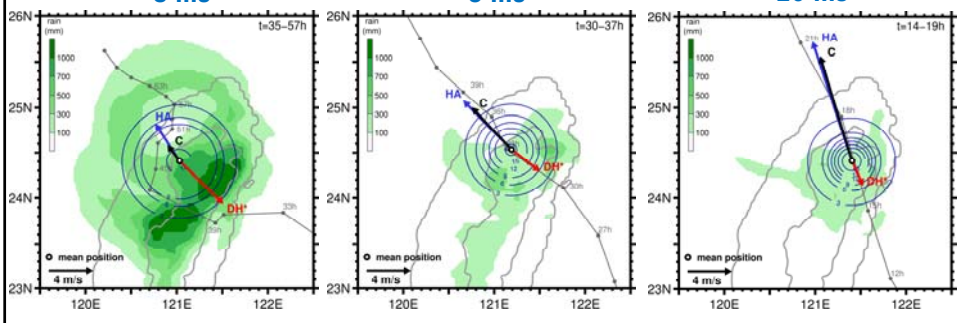
WN1 { Total PV tendency = Horizontal advection + term Diabatic heating and vertical advection term }



Sensitivity test of mean flow

Mean flow is :

-3 ms^{-1} -5 ms^{-1} -10 ms^{-1}

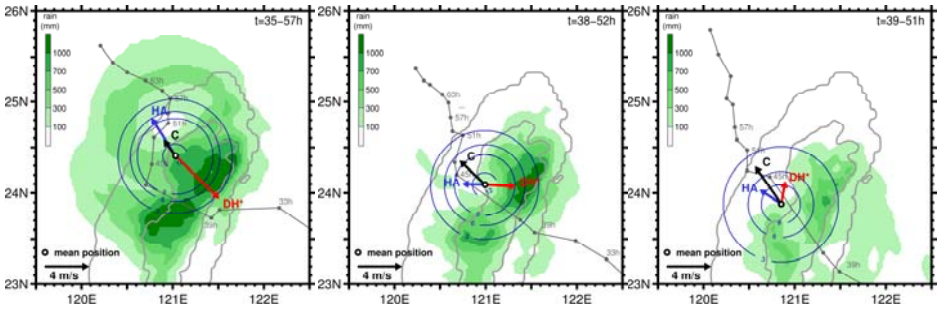


Weak mean flow - Larger rainfall amount - Larger DH* contribution

Sensitivity test of landfall position

Vortex make landfall at :

24.0 ˚N **23.6 ˚N** **23.1 ˚N**

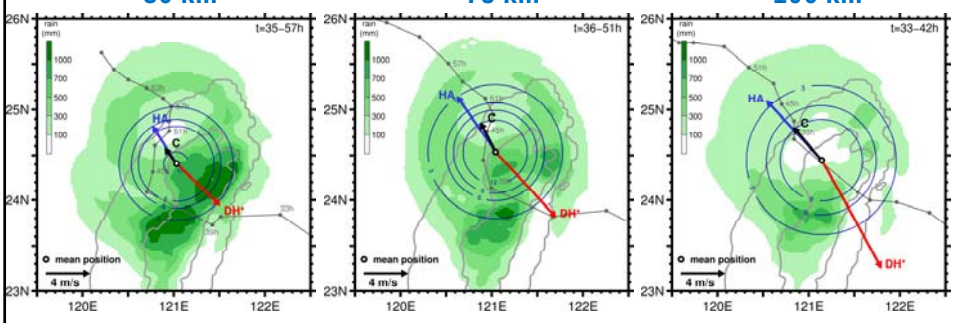


Landfall more north - Larger rainfall amount - Larger DH* contribution

Sensitivity test of vortex size

Initial vortex size is :

50 km **75 km** **100 km**



Larger vortex
- Larger translation speed (Larger HA contribution)
- Bigger asymmetry of PV contribution - Larger DH* contribution

Summary

- **In observation :**
  - TCs make landfall at northern Taiwan with slow translation speed
  - Large asymmetry rainfall amount (phase locked by Taiwan terrain)
  - Decrease of translation speed
- **In model study :**
  - Idealized WRF experiments designed and potential vorticity tendency diagnostic is applied
- **Positive feedback**
  - Slow translation speed TC – Large asymmetry rainfall

Contribution to DH* term of PV tendency through asymmetry diabatic heating

  - Slowdown type2,3 TCs' translation speed

~End~
Thanks for your attention !

Time series of PV tendency diagnostic